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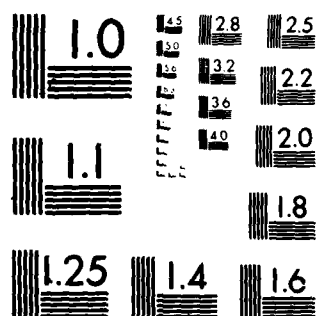
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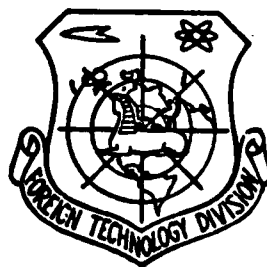
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by

Guan Congwen



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SOME PROBLEMS ON LASER SAFETY

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Submitted 7 April 1980



Laser induced harms on persons in Shanghai Institute of Optics and Fine Mechanics during more than the past ten years as reported. Some typical cases are selected and the causes for accidents analyzed. It is pointed out that the reflected light from the laser irradiated spot is a serious hazard to human eyes, and some problems on laser safety are discussed.

I. Instances of Laser-caused Human Injuries

Along with the rapid strides made in laser technology and its applications, there have been repeated cases of injury (to the human organism) caused by lasers. A considerable number of injuries were caused by laser radiation in the Shanghai Institute of Optics and Fine Mechanics; there were also injuries caused by laser apparatus (see attached table) during its operations.

We still lack a clear picture about the biological effects of lasers; it is vital to clarify the mechanism of the biological effects. Since there is a growing number of personnel in daily contact with lasers, it is important to develop protective measures to prevent laser-caused injuries. In the following, the typical cases of laser-caused injury (in the table) are briefly enumerated.

Case number 1 is a laser-beam-caused burn injury to the ocular fundus of a female researcher. When she sighted with her right eye along an argon ion laser while adjusting laser channels, another personnel (an associate) accidentally touched a power source causing a laser beam (1 watt and 4880 Å in wavelength) to enter into her ocular fundus. The injured eye immediately saw darkness, sensing blue and green vision. She had migraine headaches with fatigue. There was visual distortion, with paper viewed as wavy and a straight rod seen as bent. The patient was diagnosed as a victim of a burn injury in the area of the macula flava of right-eye retina—permanent blindness in the central vision area.

Discussion of preventive measures: the main cause of this serious incident was that the laser operating personnel was unaware of laser safety precautions and did not carry through the laser safety operational regulations.

In case number 2, a laser beam at the same elevation as the horizontal line of sight directly entered the ocular fundus of a male researcher. While adjusting a Q yttrium aluminate laser (5 pulses per second, 20 nanoseconds pulse width, 0.4 joule and about 20 megawatts in power), a laser beam directly shot into his ocular fundus. Since this was invisible light, 1.06 microns in wavelength, he failed to notice that the light beam was at the same level as his eyes. The ray obliquely shot into the patient's eye but the area of macula flava was not burned; his eyesight remained almost normal. Upon physical examination, below the papilla of optic nerve of the left eyeground, there was a bluish gray injury spot at the retina. Later, dropsy occurred with residual color vision.

Discussion of preventive measures: no "laser danger zone" sign was posted in the laser laboratory. When a laser beam (including reflection beam) is at the same height of human eyes, its injury can easily occur.

Case number 3 was an ocular fundus burn injury caused by the reflection of a light spot at laser target while the patient wore eye-protective glasses. The patient was a male researcher. When he measured the energy level of a laser-target light spot of a 5-megawatt dye laser (5 pulses per second and 5700 Å in wavelength), he could not see the light spot clearly. So he brought an exposed photographic paper to locate the position of the laser spot. The reflected laser ray bounced off the paper (reflectivity at 18%) and penetrated his protective

glasses and entered the yellow-spot area of the ocular fundus in the left eye. After treatment for more than a month, his eyesight was somewhat restored; however, he saw objects looking darker than they actually are. While viewing a yellow object, his left eye saw dark yellow while the right eye saw light yellow.

Discussion of preventive measures: the brightness of the reflected light spot laser target is very high; the beam can penetrate protective glasses (for safeguarding against 1.06 and 0.53 micron wavelength light) and injure the ocular fundus. Up to now some laser operators still carry a black paper as a movable target to locate the position of the light spot laser target; they often look at the emergence of light spot. This is very dangerous because an operator just aims at his yellow-spot area of eyeground a "laser gun." This incident also indicates that the laser protective glass has to be examined for safety and reliability.

Table of classification statistics of laser-caused injuries to human body

Classification	Case description	Number of patients
Eye injury caused by direct entry of laser ray	Ocular fundus burn injury caused by argon ion laser	1
	Ocular fundus injury while adjusting Q neodymium-infiltrated yttrium aluminate laser	1
	Entry into eye by 15-watt CO ₂ laser beam at a distance of 30 meters	1
	Less than 5 milliwatts helium-neon laser radiation entering the eye	3
Eye injury caused by reflection of laser target light spot	Ocular fundus burn injury caused by reflected beam while adjusting Q, YAG-Nd laser	1
	Ocular fundus burn injury caused by reflected beam while adjusting Q, adjustable harmonic dye laser	1
	Lens (of eye) injury caused by reflected beam while adjusting Q, adjustable harmonic dye laser	1
	Ocular fundus burn injury caused by reflected beam while adjusting Q, YAG-Nd laser channel	1

[Table continued in the following page]

[Continuation of table from the preceding page]

Classification	Case description	Number of patients
Laser-caused skin injury	Upper limb radiation injury caused by 1000-watt CO ₂ laser ray	2
	Upper abdomen radiation injury caused by 990-watt CO ₂ laser ray	1
	Upper limb radiation injury caused by 100-watt CO ₂ laser ray	2
	Radiation injuries at neck, back and upper limbs caused by 10-90 watt CO ₂ laser ray	43
Total		58

In addition, laser apparatus caused other injuries to the human organism, such as lightning stroke-caused injury, poisoning incidents, radiation injuries, and explosion incidents; these above-mentioned incidents should also be considered in preventive measures.

Case number 4 was injury to the eye lens caused by a reflected light spot at the laser target caused in a male researcher. When he operated a laser apparatus (5 pulses per second with adjustment of Q YAG-Nd laser), he carried a white paper (as an observation screen) at the target light spot. During adjustment, he squinted at the light spot of target on the white paper for a relatively long time. Later, he reported a condition of vertigo and saw a fixed black spot while seeing an object. His condition was diagnosed as cloudy lens in the right eye.

Discussion of preventive measures: laser operators search for the light spot at the laser target during their routine work. Since the brightness of the reflection ray is very high, strict safeguard measures should be followed while wearing effective eye-protective glasses. Double precautions should be taken with repetition frequency or continuous wave laser.

Case number 5 was a third-degree burn injury to skin of a male researcher while operating high-power CO₂ laser. He performed laser experiments throughout one night. Next morning, his right upper abdomen was penetrated by 990-watt laser ray for one second. Five layers of clothing (including his white working robe)

he wore were burned through in addition to his skin, but he did not feel pains. Upon physical examination, there was a burn wound (of 1 cm long) at the right upper skin of the abdominal wall. A piece of charred flesh the size of a soybean was removed from the wound. There was a third-degree wound on the skin.

Discussion on preventive measures: incidents are likely to occur when the researcher is feeling fatigue or work under tight schedules. At that time, stricter laser safety regulation has to be closely followed. When necessary, on-duty safety supervisory staff members should be on the premises.

II. Analysis of Laser-caused Injury Incidents

There were quite a number of cases of laser-caused injuries at the Shanghai Institute of Optics and Fine Mechanics; relatively serious injuries occurred in some cases. Several major causes are lack of laser safety operation regulation. In some laboratories, there were no signs, such as a laser danger zone and a high tension danger zone. In some cases, safety regulations were just overlooked when laser operators were busy. Day in and day out, causes of incidents were not studied and their elimination was not given appropriate attention. Incidents occur when there is carelessness.

New laser operators did not receive laser safety education. No safety precautionary measures were announced to personnel on temporary duty in laser operation. Safeguard protective implements were not worn. The above-mentioned areas of negligence can cause incidents.

As revealed in the laser-caused eye injuries at the Shanghai Institute of Optics and Fine Mechanics, proper attention should be given to high brightness levels in laser channel reflected beams and to the light-spot reflection of the laser target: these high brightness levels can cause major damage to eyes. Since laser operators have to deal constantly with laser target light spots, such as the measurement of light-spot energy, cutting, welding, and use of the laser knife, and even sometimes staring (with both eyes) at target light spot. If no effective precautions are taken, this situation tends to cause latent or manifest injuries to eyes. The reflected beams of repetition frequency lasers and continuous-wave laser can also injure eye lens. Danger to eyes may also be caused by adjustable

Q lasers, invisible light lasers, and the work environment of poorly lighted rooms. We must analyze and evaluate every laser system to specify effective precautionary measures; thus, laser-caused injuries can be avoided.

Because of advances in laser technology, there are many laser equipment accessories. Thus, new injury causing factors will also occur. For example, short-pulse radiation (emitted from laser apparatus), liberated toxic gases, and lightning incidents at laser apparatus are common occurrences. These problems with (new and old) industrial hygiene and labor hygiene are being studied and resolved by the related departments.

III. Double Efforts in Strengthening Laser Safety Precautionary Measures

(A) Before the state promulgates laser precautionary regulations and laser technique safety standards, at least the three following points should be considered in laser precautionary activity:

(1) Precautionary protection against laser radiation injuries of different wavelengths and different intensity lasers;

(2) Safety protection at various sectors of a laser installation (including laser-application installation); and

(3) Pollution treatments of contaminated air, water source, and other harmful materials liberated during laser-apparatus operation and during research and manufacture of laser apparatus.

At present, we must given attention to the current situation by specifying concise laser safety operation rules for lasers of injury threshold value and above. Timely updating should be carried out for strict compliance.

(B) A system of laser safety precautionary education should be established. Laser operators should understand laser protective and precautionary principles, learn to operate protective accessories, and actively carry out protection precautionary measures. In particular, new laser operators should receive laser

safety education before beginning their work; this safety education should be conducted systematically. For persons who have contact with lasers only for short periods (such as visitors and patients receiving laser treatment), they should be briefly familiarized with laser safety precautionary measures.

(C) Protection against laser radiation-caused injuries to skin and internal organs

There have been many papers reporting on protection against lasers for possible injuries to the eyes and skin. However, the laser protective mechanism has not been fully clarified. So studies should be made on the possibility that a laser may penetrate the walls of the trunk and injure internal organs. As revealed in experiments, for guinea pigs with muscles and cranial bones intact, the rate of transparency (for lasers) at the cranium is 0.55 percent [1]. By using a ruby laser for entering the cerebrum at the head of guinea pigs, the minimum energy level causing apparent injury is less than 19.22 joules per square millimeter [2]. Further studies should be made on human objects because the energy value is much higher. We should avoid use of high energy and high power lasers aimed at the head, chest and abdomen. When necessary, we should calculate the local absorption of laser energy by the walls of the trunk, the extent of laser reflection and penetration, and possible depth of laser penetration into the trunk walls in order to avoid injuries to internal organs. Necessary laser treatments with safety rules complied with can further enhance therapy.

(D) Protection of respiratory passage: lasers can ionize the air, thus liberating ozone. Penetration of a CO₂ laser beam into refractory brick can liberate toxic gases, such as beryllium. A laser knife can char and gasify protein liberating very odorous, noxious gases. Noxious gases are liberated from the target chamber in laser fusion experiments, so effective ventilation and gas removal should be conducted for de-contamination treatment. Smoking should be prohibited in laboratories.

(E) Intensify laser protection and precautions in science research and administration. The interaction between laser and living tissues underlies the biological effects of lasers. These two above factors and environmental conditions

changing constantly. Every laser system should be analyzed to prevent fest and latent injuries. Effective eye protective glasses should be developed and approaches should be considered in taking preventive measures. We must realize experiences from incidents of laser-caused injuries to the humanism and follow progress in preventive precautions both at home and abroad. Necessary physical examinations should be conducted and case files of laser medical examination should be compiled. The medical personnel should study the full factors affecting the human organism at the sites of scientific research production in order to intensify studies of laser protective measures. Laser protective activity involves many sciences and departments, so we should cooperate soundly performing laser protective work, to double our efforts in management, to safeguard the health of general laser workers.

RATURE

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